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A STUDY OF THE ELECTRICAL CHARACTERISTICS OF SOME EXPLOSIVES AND EXPLOSIVE MIXTURES

by

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TABLE OF CONTENTS

Objects

To investigate the electrostatic sensitivity of some secondary explosives.

To develop a conductive mixture possessing superior simultaneity behavior.

Introduction

The work described herein is the result of studies aimed at (a) determining the electrostatic sensitivity of secondary explosives and (b) developing conductive mixtures which would give reproducible functioning times in the range of 0.10 microsecond or a standard deviation of 0.030 microsecond.

The study of the electrostatic sensitivity of explosives was first conducted at the Bureau of Mines in 1942 (Ref. 1) to determine the hazard that would arise due to a spark discharge from an electrostatically charged human body. It was calculated that 0.015 joules was the approximate energy to be so obtained. A report by Kirk clearly presents the problems in the field of electrostatic sensitivity and electrical initiation (Ref. 2).

The use of explosives containing electrically conductive material in the bridgeless electric primer was reviewed by R. F. Wilkerson in 1949 (Ref. 3). A high speed electric primer was reportedly used by the Germans in a 20 mm electric primer. The functioning time of lead azide-graphite mixture was in the microsecond range. The British used lead styphnate/tetrazene and later graphited lead azide which gave functioning times between 1 and 5 microseconds. Remington Arms and Frankford Arsenal developed the first wireless initiators in this country. In 1950, the University of Arkansas prepared a literature survey on explosive initiators in which conductive mixtures are described and some interpretation of the results is presented (Ref. 4). According to this survey, conductive mixtures possessing good simultaneity must have the following characteristics: (a) one joule or less for initiation, (b) output energy sufficient to initiate high explosives, and (c) two or more items containing the mixture should fire with a spread of 0.10 microsecond or a standard deviation of 0.030 microsecond.

For every short functioning times, lead styphnate and lead azide conductive mixtures have been studies (Refs. 5 and 6). Chemically bound graphite mixtures are reported to be superior to mechanical mixtures for the same material and percentage of graphite. It has been shown that the energy necessary for the ignition of conductive mixtures containing graphite can be controlled by the graphite content.

Results

The electrostatic spark-gap sensitivity test results for fourteen (14) explosives and explosive compositions are given in Table I. A comparison of these results with those of other investigators is shown in Table II for six secondary explosives.

Lead azide/graphite conductive mixtures examined for reproducible functioning times are reported in Tables III, IV, V and VI.

Discussion of Results

The results in Table I, besides giving the electrostatic sensitivity in terms of energy, also show the voltage that is necessary when a 500 MMF capacitor is used. It should be noted that tetryl has a zero initiation energy value lower than 0.015 joule. This amount of energy (0.015 joules) is the most commonly accepted energy value that an individual may have with a charge of 10,000 volts (the assumed body capacity 300 MMF) (Ref. 1).

It is the opinion of some investigators that the spark ignition energy varies with the voltage (Ref. 9). These results show that as the voltage is increased the zero-ignition energy decreases. This means that the higher a human being is charged, the greater is the potential hazard increased.

An examination of the results in Table II reveals that the order of sensitivity of these explosives is nearly the same based on data obtained with the new high voltage tester or the Bureau of Mines data (Refs. 5, 6, 7). The results reported here do not agree with those obtained by Wyatt (Ref. 8).

The functioning times of three series of eight detonator test fixtures of 30 milligrams conductive lead azide/graphite (98.7/1.3) and 220 milligrams conductive PETN/graphite (95/5) loaded at 16,000 psi are shown in Table III. The average functioning time of the three are in good agreement. However, their standard deviation is greater than the 0.030 microsecond desired. The electrical input energy was 1.12 joules (IMFD/1500 volts). All subsequent tests used the same fixtures and firing energy.

The effect of variation in sample sizes of conductive lead azide/graphite (96.7/3.3) and conductive PETN/graphite (95.5) leaded at 16,000 psi is shown in Table IV. The first three columns show the average functioning times of 30 milligrams conductive lead azide/graphite and 220 milligrams conductive PETN/graphite (95.5) loaded at 16,000 psi which again have standard deviations larger than 0.030 microseconds. The other series show the functioning times of 50 mg, 60 mg and 70 mg conductive lead azide/graphite (96.7/3.3) and 200 milligrams conductive PETN/graphite (95/5) added to each loaded at 16,000 psi. There is an improvement in the standard deviations. The evaluation of 60 milligrams conductive lead azide/graphite and 200 milligrams conductive PETN/graphite loaded at 16,000 psi are given in Table V. The standard deviations do show a decrease with an increase in graphite content of the conductive lead azide. There was one series that gave erratic results (test number 25). No explanation could be found for this. The graphite content of the conductive lead azide was increased to 7-1/2 percent. The average functioning time results of the two series of 60 milligrams conductive lead azide/graphite (92.5/7.5) and 200 milligrams of conductive PETN/graphite (95.5) were 1.692 and 1.706 microseconds, and standard deviations 0.031 and 0.030 microseconds respectively. The conductive lead azide/graphite (92.5/7.5) and conductive PETN/graphite (95/5) can be so loaded at 16,000 psi and electrically initiated by a 1.12 joules to give reproducible simultaneties with a standard deviation of 0.030 microsecond and sufficient output energy to initiate tetryl pellets.

Summary

Another apparatus for determining the electrostatic sensitivity of explosives has been built and tested. The results indicate that it can be used to determine the order of sensitivity of explosives. It is simple and safe to operate. The initiation energy and voltages have both been given in this study. There was no apparent difference in order of sensitivity when a lower capacitor (500 MMF) and higher voltages were used. The results still show that tetryl is the most hazardous secondary explosive.

The functioning time of conductive lead azide is shown to be related to the graphite content. It has been long realized that there is an optimum percentage of conducting material for each specific use of conductive explosives. It was reported by the Germans that chemically bound graphite of a lower percentage would be suitable for reproducible short functioning times. It was found that such graphite/lead azide composition was very difficult to prepare. Our difficulty was the inability to control the amount that would be occluded, and its distribution. The high purity colloidal lead azide mixtures of 6-7 1/2% graphite possess functioning times of 1-2 microseconds and standard deviations of 0.030 microsecond. This two-component system has sufficient output to initiate tetryl and other high explosives.

Experimental Procedures

Loading of Electrostatic Test Cup:

The material was carefully placed in the standard die cup and leveled off with a wooden spatula. The weight of the material was usually 10-25 milligrams.

Electrostatic Test Procedure:

The loaded test cup was placed directly under the needle point and on the base plate. A gap was set with a precision gauge of 0.005 inch thickness. The door of the test chamber was connected to the power supply by a micro switch which allowed the high voltage to be on only when the door was closed. The charging voltage was set by adjusting the built-in powerstat. For each sample of a given material an attempt was made to ignite the sample by discharging the capacitors. Ten tests were made at each energy or voltage level. The results were recorded as to the number of ignitions per voltage level.

Preparation of Conductive Mixtures:

Blending - The calculated weights of dry materials were blended by tumbling in a rubber beaker which was rotated at 25 - 35 rpm by an air driven motor.

Ball Milling - Ball milling was done using chloroform or absolute methyl

alcohol as a milling medium and with steel balls 1/4" - 3/4" diameter. The materials and medium were placed in a rubber container and rolled on a rolling mill for 2 - 3 hours.

Method of Loading Test Fixtures:

The samples were weighed on a Roller-Smith balance and poured in test fixture (Diagram 1) held in a loading assembly. The sample was consolidated with a Denison Midget press (1 ton on 1 1/2 inch diameter ram). For pressure near the bulk densities of the material, slight compression was obtained by using a hand operated arbor press.

Simultaneity Tests:

Simultaneity tests were conducted by mounting eight (8) of the loaded parts (with tetryl pellets attached), in a board and firing them electrically. The light emitted by the tetryl was recorded by a streak camera. The energy used to fire these loaded parts was approximately one joule. This energy was obtained by discharging a 1 microfarad condenser charged at 1500 volts.

TABLE I

The Electrostatic Discharge Energy and Voltages for Zero Ignition
(Capacitance was 500 MMF and a gap setting of 0.005".)

Explosives	Voltage*	Energy (Joules)*
Copper Chlorotetrazole	6,000	0.009
Tetryl (on 100 sieve)	8,000	0.025
PETN/TNT (13/100)	8,000	.025
Composition B	12,000	0.036
TNT (thru 100)	12,000	.036
PETN (2.6 micron)	12,000	0.036
RDX	20,000	.100
HEX M-24.1	20,000	.100
PETN (Special Crystal)	24,000	.144
RDX/Acetylene Black (90/10)	24,000	.144
RDX/Acetylene Black (75/25)	32,000	.256
MOX-2B	36,000	.290
Explosive D	40,000	.400
B-HMX	40,000	.400
HEX-48	60,000	.900

* Maximum voltage and energy allowable above which ignitions will occur.

TABLE II

ELECTROSTATIC SENSITIVITY DATA

(Secondary Explosives and Explosives Compositions)

	HIGHEST ENERGY (JOULES) FOR ZERO IGNITION PROBABILITY				
Explosives	Present Results	Bureau of Mines 1943 (Ref. 1)	Bureau of Mines 1946 (Ref. 2)	Bureau of Mines 1954 (Ref. 6)	NOL 1959 (Ref. 8)
Tetryl	0.025	0.020	0.007	0.0005	1.25
PETN	0.036	0.31	0.062	--	0.085
Composition B	0.036	--	--	0.00062	--
TNT	0.036	0.077	0.062	--	--
RDX	0.100	0.62	--	--	0.80
Explosive D	0.400	0.10	0.025	0.16*	--

* Reference 7.

TABLE III

Evaluation of the Simultaneity of Conductive lead azide/graphite (98.7/1.3)[a]

Functioning Time, μ sec

Test No.	8	9	10
	1.958	2.110	2.154
	2.196	2.123	2.121
	2.085	1.920	2.139
	2.148	2.143	2.230
	2.132	2.127	2.018
	2.041	2.150	2.081
	2.085	2.132	2.092
	2.168	2.088	2.078
Average, μ sec	2.102	2.105	2.114
γ(Standard deviation)	0.077	0.075	0.069

NOTE: [a] 30 mg conductive lead azide [1] and 220 mg conductive PETN[2] loaded at 16,000 psi, firing energy is 1.12 joules (IMFD/1500V base charge conductive PETN-graphite (95/5)

TABLE IV

The effect of the Variation in Weights of Conductive lead azide-graphite (96.7/3.3)/ Conductive PETN-graphite (95/5)[(a)]

Functioning Time, μ sec

Test No	11	12	13	19	23	24
wt. of 96.7/3.3 P6N$_6$/graphite (gram)	0.030	0.030	0.030	0.050	0.060	0.070
wt. of 95/5 PETN/ graphite (gram)	0.220	0.220	0.220	0.220	0.220	0.220
	2.079 μsec	-	2.137 μsec	1.813 μsec	2.248 μsec	1.991 μsec
	2.127	2.124 μsec	1.784	1.880	1.952	2.090
	2.040	2.193	2.132	1.826	2.062	2.102
	2.143	2.138	2.125	1.793	1.958	1.882
	1.768	2.114	2.195	1.830	2.139	1.892
	2.058	2.119	1.815	1.903	1.834	
	1.858	1.755	2.135	1.737	2.011	1.895
	2.184	1.770	2.132	1.779	1.882	1.950
Average Times (μsec)	2.031	2.036	2.120	1.809	2.019	1.952
Standard deviation (γ)	0.135	0.142	0.068	0.046	0.119	0.087

NOTE: (a)

Loading pressure is 16,000 psi and firing energy 1.12 joule (IMFD/1500 Volts)

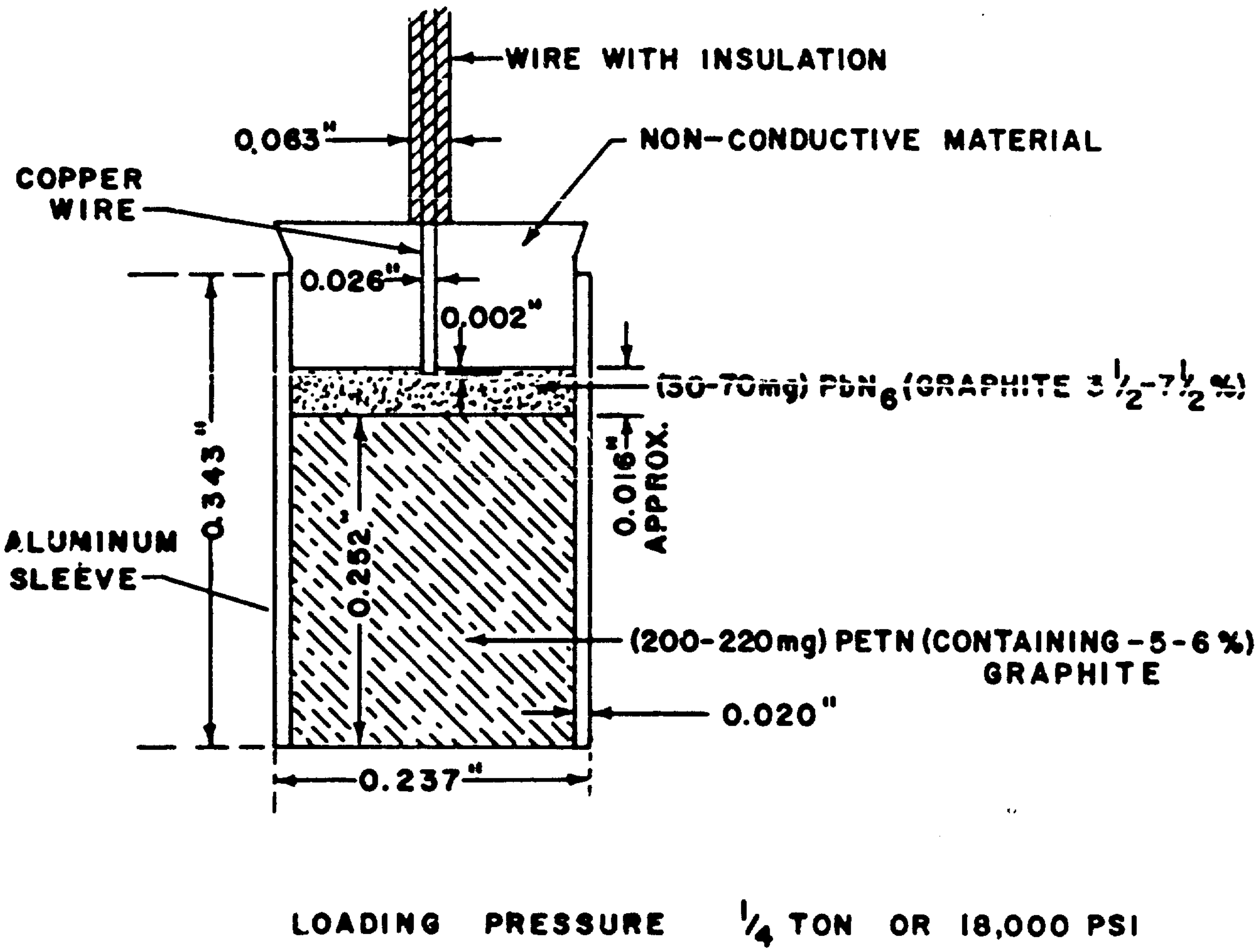
TABLE V

Evaluation of the Simultaniety of (95/5) lead azide-graphite conductive mix (95/5)[a]

Functioning Time, μ sec

Test No	21	22	25	26	27	28
	1.768	1.749	3.696	1.770	1.681	1.801
	1.672	1.812	3.720	1.770	1.692	-
	1.772	1.721	3.739	1.930	1.745	1.702
	-	1.715	3.675	1.701	1.835	1.801
	1.705	1.780	3.611	1.774	1.908	1.712
	1.793	1.746	3.719	1.817	1.771	-
	1.791	1.740	3.684	1.716	1.810	1.765
	1.771	1.743	3.714	1.817	1.725	1.774
Average Time, μsec	1.753	1.751	3.695	1.787	1.774	1.761
Standard deviation (γ)	0.039	0.032	0.042	0.074	0.074	0.032

Note: [a] 60 mg Conductive lead azide/graphite (95/5), 200 mg Conductive PETN/graphite (95/5), loaded at 16,000 psi, and firing energy 1.12 joules (1500V/IMFD)



TEST FIXTURE USED IN CONDUCTIVE MIXTURE TESTING

DIAGRAM 1

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